The CORE datasets from Large and Yeager

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Abstract

These notes describe the release of the *CORE forcing* developed by Bill Large and Steve Yeager at NCAR for global ocean-ice modelling. CORE.v1 includes both an interannually varying forcing (IAF) from 1958-2004, and a normal year forcing (NYF) derived from the interannual forcing. CORE.v1 is detailed in the technical report Large and Yeager (2004). CORE.v2 from Large and Yeager was released during May 2008; a bug fix was released 8July2008; and extended data files in June2009. This dataset is documented in Large and Yeager (2008). The CORE.v2 release updates the interannually varying forcing, now extending from 1948-2006, as well as the NYF. Both CORE.v1 and CORE.v2 are supported at NCAR and GFDL for use in studying global ocean-ice dynamics.

These release notes, the CORE datasets, support code, and further documentation can be downloaded from

http://data1.gfdl.noaa.gov/nomads/forms/mom4/CORE.html

1   Introduction

This document describes the release of the CORE datatsets. It was written by GFDL scientists in support of the CLIVAR Working Group for Ocean Model Development (WGOMD) Coordinated Ocean Reference Experiments (CORE). A key element facilitating the existence of CORE is the work of Bill Large and Steve Yeager. They developed algorithms that modify or "correct" various atmospheric datasets, so that these datasets can be used to derive surface fluxes needed to integrate global ocean-ice models. The Large and Yeager (2004) algorithms have been used to produce Version 1 of the interannually varying forcing (IAF) CORE.v1 for years 1958-2004, as well as a normal year forcing (NYF) derived from the interannual forcing. We refer to these "corrected" datasets as CORE-IAF.v1 and CORE-NYF.v1. Large and Yeager (2008) present updated algorithms for the interannual dataset 1948-2006, thus producing CORE-IAF.v2. CORE-NYF.v2 is derived using the new corrections, but applied to the original uncorrected NYF data files.

At NCAR, the Large and Yeager corrections are applied to the uncorrected datasets during the runtime of a particular ocean-ice simulation. At GFDL, corrections are applied to the uncorrected datasets to produce a corrected dataset, which is then used to integrate the ocean-ice models. The NCAR strategy is preferred when developing the correction algorithms. Once a final suite of corrections has been derived, it is sensible to work with the corrected datasets. This web site provides options for both approaches.

2   The CORE dataset web page

We summarize here the contents of the CORE dataset web page

http://data1.gfdl.noaa.gov/nomads/forms/mom4/CORE.html

2.1   Datasets

The CORE dataset web page contains the following datasets.

- Version 1 datasets

    - Uncorrected Normal Year Forcing (unCNYF.v1)
    - Uncorrected Interannual Forcing (unCIAF.v1)
    - Corrected Normal Year Forcing (CORE-NYF.v1)

– Corrected Interannual Forcing (CORE-IAF.v1)

- Version 2 datasets

  – Corrected Normal Year Forcing (CORE-NYF.v2)
  – Uncorrected Interannual Forcing (unCIAF.v2)
  – Corrected Interannual Forcing (CORE-IAF.v2)

Each of the above datasets contain the following fields on a spherical grid of 192 longitude points and 94 latitude points (T62 atmospheric grid):

- annual mean river runoff (1 time step for full dataset)

- monthly varying precipitation (12 time steps per year)

- daily varying shortwave and longwave (365 time steps per year–no diurnal cycle and no leap years),

- six-hourly varying 10m temperature, density, humidity, zonal velocity, meridional velocity, and sea level pressure (4×365 time steps per year–no leap years).

The unCIAF.v1 and unCIAF.v2 datasets are identical for years 1958-2003. However, both the NCEP fields and the GISS radiation data for 2004 were modified subsequent to the release of unCIAF.v1. Hence, year 2004 in unCIAF.v2 includes the changes. The precipitation for year 2004 has also been updated for months 10-12 in unCIAF.v2.

2.2 Support code and documentation

Besides the present set of notes and the datasets, the CORE web page also contains the following files.

- Version 1 support files

  – Large and Yeager (2004): This report details both the uncorrected and corrected data sets used to produce the forcing fields. In particular, it provides an atlas of the fluxes produced when using Reynolds SSTs and the NCAR bulk formula to compute fluxes from the atmospheric state.
  – Griffies et al. (2009): (CORE_NYFv1.pdf): This manuscript documents seven global ocean-ice models run with CORE-NYF.v1 for 500 years.
  – The Fortran code `advance.f90` provided by NCAR corrects the raw data. This code may be of use for those who compute the data corrections as the model integrates.
  – The Ferret code `make_data.csh` provided by GFDL implements the algorithms from `advance.f90` in a Ferret script.
  – The Fortran code `ncar_ocean_fluxes.f90` provided by GFDL computes the NCAR exchange coefficients recommended for use in CORE. This is the same as the Version 1 release.
  – The sea surface salinity restoring file `PHC2_salx.nc` provided by NCAR for use in computing a restoring salt or fresh water flux with CORE.

- Version 2 support files

  – The Large and Yeager (2008) paper documents the CORE-IAF.v2.
  – `README_COREv2` is a README file for the release of CORE-v2.0 from NCAR.
  – The Fortran code `datm_physTN460.F90` provided by NCAR corrects the raw data in the case that a user wishes to make the corrections during a run (online) rather than prior to the run.
  – The NetCDF file `tn460nyf.correction_factors.T62.121007.nc` provides the correction factors that are applied to the uncorrected datasets if users wish to run with `datm_physTN460.F90`.

- The Ferret code `make_data_CIAFv2.2008_06_18.csh` (updated July 2008 from the original file `make_data_CIAFv2.2008_04_22.csh`) represents the GFDL implementation in a Ferret script of algorithms from the NCAR file `datm_physTN460.F90`.
- The Fortran code `ncar_ocean_fluxes.f90` provided by GFDL computes the NCAR exchange coefficients recommended for use in CORE. This is the same file as in the Version 1 release.
- The sea surface salinity restoring file `PHC2_salx.nc` provided by NCAR for use in computing a restoring salt or fresh water flux with CORE. This is the same files as the Version 1 release.

We provide both the uncorrected and corrected forcing fields for two reasons.

- The user may wish to run simulations as at NCAR whereby corrections are applied to the uncorrected fields at runtime by using `advance.f90` for CORE.v1 or `datm_physTN460.F90` for CORE.v2. This procedure facilitates further refinement to the corrections without needing to generate a new "corrected" dataset.

- At GFDL, we perform corrections prior to runtime using the above Ferret script.

3 Releases of CORE-IAF.v2

This section documents the releases of CORE-IAF.v2.

3.1 May 2008: Initial Release

The initial release of CORE-IAF.v2 occurred near the end of May 2008.

3.2 July 2008: Bug Fix

Soon after the first release, Simon Marsland from CSIRO Marine and Atmospheric Research in Aspendale, Australia identified the following two problems:

- The air temperature was about $20°C - 30°C$ warmer around Antarctica than with the CORE-IAF.v1 release. This spurious result arose from a bug in the Ferret script `make_data_CIAFv2.csh` used to implement the Large and Yeager corrections, where

$$\text{let cfac=cos(atan(1)*8/1460-0.298)}$$

should in fact read

$$\text{let cfac=cos(atan(1)*8*l[g=t\_10]/1460-0.298)}$$

The bug also spuriously affected the precipitation field, since air temperature determines how precipitation is partitioned into liquid and solid.

- The netCDF data files in CORE-IAF.v2 had a time axis which could lead to problems with runs over multiple years. Andrew Wittenberg at GFDL has provided a self-consistent time axis for the various data files in the 8 July 2008 release.

The 8July2008 bug fix release of the CORE-IAF.v2 dataset has updated ALL of the datafiles.

3.3 June 2009 extended data

In June 2009, we extended the interannual dataset from 1958 back to 1948 for Version 2 of the IAF. Because the calendar meta-information changed in the datafiles, from origin at 1958 to new origin at 1948, we replaced ALL of the data files for the IAF. The data did not change for the years 1958-2006, but the calendar did, with the new origin.

Note that in addition to providing each data file split into individual years, there is also a merged data file for each forcing field, containing all of the years 1948-2006.

4 Reasons favouring the use of CORE forcing

The release of the CORE.v1 and CORE.v2 datasets by Large and Yeager provides the global ocean climate modeling community with an important advance in our ability to integrate ocean-ice models without a fully coupled atmospheric GCM. This advance builds in many ways on an earlier effort by Röske (2001) for a Pilot-Ocean Model Intercomparison Project (POMIP). There are generally various datasets that can be used for running coupled ocean and sea ice models. However, we prefer the CORE.v1 and CORE.v2 data for the following reasons.

- The data, which combines reanalysis with satellite data, has advantages over that based solely on reanalysis (Röske, 2001, was based solely on ECMWF). Advantages are discussed in Large and Yeager (2004).

- Both normal year *and* interannual data are provided in CORE.v1. Many researchers find the use of interannually varying data to be more interesting, since it better facilitates comparisons of model simulations with ocean observations.

- The datasets are documented and supported by NCAR, with extensive refinement as more data is gathered. GFDL has agreed to support the release of corrected versions and to document this web page to assist those who wish to use the datasets. Future releases of this data can be expected as improvements are made to the data products and to our understanding of their biases.

- The CLIVAR WGOMD has recomended the Large and Yeager derived datasets for use in various model comparison efforts, such as that documented in Griffies et al. (2009).

5 Comments on the data and experimental methods

We now present some comments on particular aspects of using the CORE datasets. Any recommendations provided here are subject to modifications as different modeling groups gain experience with this forcing. Note that Griffies et al. (2009) documents seven global ocean-ice models employing the CORE-NYF.v1 forcing for 500 years. Experience with the interannual varying data at GFDL is minimal, as this data has only recently been developed. However, NCAR has been working with earlier versions of this dataset for some years, with the papers by Doney et al. (2003) and Doney et al. (2007) providing guidance for its use. With the release of CORE-IAF.v2, we anticipate much more use of this dataset by the ocean climate modeling community.

5.1 Initial conditions and experiment duration for CORE-NYF

For the CORE-NYF.v1 simulations, generally at least 100 years is simulated, with 500 years preferred for reasons discussed in Griffies et al. (2009). The models are initialized in the ocean with Levitus, and sea ice models are generally begun with a state taken from an earlier simulation.

5.2 Regarding the use of surface salt fluxes versus water fluxes

An ocean model that allows for the use of a real water fluxes transferred across the ocean surface, such as naturally occurs for free surface formulations, has the option of applying the surface salt flux as a corresponding water flux. This approach, however, is not encouraged, for the following reasons. First, the salt flux is an artifact of decoupling the ocean model from the atmosphere. It thus should be seen as a mere means to keep the model's overturning circulation from becoming overly unstable to allow for the simulation to be of use for studying mechanisms of climate variability. Second, by converting the salt flux to a fresh water flux, we are generally modifying the total water added to the ocean, unless some form of a global normalization is applied. Modifications of water content, either local or global, induce a spurious barotropic flow, and will generally corrupt the use of the simulation for studying sea level variations.

5.3 Recommendations for CORE-IAF experimental design

The following procedure is based on extensive experience from the modeling group in Bergen, Norway (Helge Drange: `helge.drange@gfi.uib.no`), with emphasis of the North Atlantic subpolar gyre. We caveat the following discussions by noting that different model systems may respond differently. Furthermore, some scientific problems may require longer spin-up than the 4-6 cycles recommended here (e.g., the marine cycling of carbon). Conversely, certain problems may require less cycles. Nonetheless, the following procedure is offered as an example of what other groups may choose to follow.

- Initialise the model based on climatological temperature and salinity fields, for instance from the World Ocean Atlas

$$http://www.nodc.noaa.gov/OC5/WOA05/pr\_woa05.html$$

  and/or the Polar Science Center Hydrographic Climatology version 3.0 (PHC3.0)

$$http://psc.apl.washington.edu/POLES/PHC/Paper98.html$$

  The ocean velocity is zero and there is a 2m thick sea ice cover with extent according to climatology (for instance see

$$http://nsidc.org/data/seaice\_index.$$

- Spin up the model with daily varying reanalysis fields from CORE-II until a quasi-steady solution is obtained. Experience indicates that for studies of the upper ocean, typically at least N=4 to N=6 cycles (200-300 years) are required. Each cycle past the start is initialized by the ocean state at the end of the previous cycle.

- During the spin-up phase, apply a relaxation of sea surface salinity (SSS) with a relaxation time scale of 30 days for a 50m thick mixed layer, linearly decreasing with thicker mixed layers. No relaxation of surface temperature is applied, since the heat fluxes are computed from the bulk formulae. Additionally, there is no relaxation of sub-surface waters nor sea ice. Continental runoff is included by adding freshwater into the appropriate coastal grid cells.

- Importantly, the mismatch between model and climatological sea surface salinity, $\Delta(SSS)$, is limited to

$$|\Delta(SSS)| < 0.5\text{ppt} \tag{1}$$

  in the computation of the surface salinity relaxation. This limit avoids extreme relaxation fluxes that may occur, for example, in the vicinity of the western boundary currents that are generally not realistically represented in coarse OGCMs. If too much fresh water is added due to large biases in the western boundary current, then this potentially large amount of fresh water will be transported poleward, which will spuriously weaken the Atlantic overturning circulation. A summary of this unstable feedback is given in Griffies et al. (2009).

- If focusing on quantities such as the Atlantic overturning, then one should gauge the degree of quasi-stationary by examining the behaviour of the overturning. Additionally, time series of temperature and salinity as a function of depth may be used to determine suitability of the spin-up for studies being considered.

- When a quasi-steady solution is obtained after N cycles, the restoring surface salinity flux is stored on the horizontal model grid with a weekly temporal resolution, averaged over cycle N+1 and saved either weekly or daily.

- The production run starts with cycle N+2. Now the diagnosed, weekly or daily averaged (but interannually invariant) salinity flux from cycle N+1 is applied. In addition, the conventional surface salinity relaxation is applied, but with the relaxation time reduced by an order of magnitude; e.g., to 360 or 720 days for a 50m thick upper ocean.

- It is the cycle N+2 that is used to focus analysis on the particular feature of interest.

5.4 Interannual forcing without leap-years

The interannual forcing fields in CORE-IAF.v1 and CORE-IAF.v2 do not contain leap-years. That is, each year has the same length of 365 days. This limitation may introduce some difficulties for those using the data for reanalysis efforts. However, the decision was made by NCAR to jettison the leap-years since many researchers find this to be more convenient given their software infrastructure.

5.5 Padding of years for the IAF

The IAF datasets for CORE-IAF.v1 and CORE-IAF.v2 are split into individual years with no overlap. The transition from one year to another is a detail that is left to the respective modellers, as it is a function of the modeller's time interpolation code. At GFDL, we pad the corrected IAF data with a day on each side of the year boundary in order to smoothly time interpolate from one year to another.

Note that for CORE-IAF.v2, we also provide the merged data files for all years 1958-2006. This single file should be usable by most time interpolation schemes for running a single realization of the full dataset.

5.6 Air density and sea level pressure

The subroutine `ncar_ocean_fluxes.f90` computes the exchange coefficients for momentum, evaporation, and sensible heat according to the equations documented in Large and Yeager (2004) (see their Section 2.1). After computing the exchange coefficients, the model computes air-sea fluxes based on equations (4a)-(4d) in Large and Yeager (2004). This calculation requires the air density. There are three ways to get this density, each of which result in rather small differences.

- The air density at 10m is provided in the uncorrected fields for version 2 of the IAF. Large and Yeager present no corrections to this field, so it can be used in CORE-IAF.v2.

- One may set air density to a constant 1.22kg m^{-3} (see Section 4.1 of Large and Yeager (2004)).

- One may use the sea level pressure provided in the CORE datasets, and then use the ideal gas law to compute the air density.

The preferred method depends on the structure of the flux computation code that each modeler maintains. At GFDL, we use the sea level pressure and ideal gas law, so we do not make use of the 10m air density dataset.

5.7 Radiative heating

Radiative heating is provided from the shortwave and longwave datasets. The shortwave and longwave datasets represent *downwelling* radiation. The *net* shortwave radiation $Q_{\text{SW net}}$ transferred into the ocean is a function of the albedo as shown by equation (11) in Large and Yeager (2004). As discussed in Section 3.2 of Large and Yeager (2008), a latitudinally dependent albedo is used to compute the net shortwave in CORE-IAF.v2.

The net longwave radiation transferred into the ocean is given by the downwelling longwave radiation minus the loss of heat associated with re-radiation to the atmosphere as given by the Stefan-Boltzmann formulae σT^4 as shown by equation (12) in Large and Yeager (2004).

The CORE datasets provide a single shortwave radiation field. However, many ocean optics models make use of four different partitions of this shortwave field: visible direct, visible diffuse, infrared direct, and infrared diffuse. NCAR recommends the following frabricated downward shortwave components for the purpose of mimicing a more complete atmospheric radiation model:

$$Q_{\text{visible direct}} = 0.28 \, Q_{\text{SW net}} \tag{2}$$

$$Q_{\text{IR direct}} = 0.31 \, Q_{\text{SW net}} \tag{3}$$

$$Q_{\text{visible diffuse}} = 0.24 \, Q_{\text{SW net}} \tag{4}$$

$$Q_{\text{IR diffuse}} = 0.17 \, Q_{\text{SW net}} \tag{5}$$

5.8   Surface temperature forcing

There is generally no restoring to surface temperature. Instead, turbulent heat fluxes are derived from the NCAR bulk formulae using the model SST and the 10m atmospheric fields, and radiative heating is provided by shortwave and longwave fluxes.

We initially tried to use the GFDL bulk formulae in our CORE-NYF.v1 simulations. However, the fluxes produced from the two bulk formulae are quite distinct when running with observed SSTs. In particular, the wind stresses are larger with the GFDL formulation (which follows ECMWF) and the latent heat fluxes are larger with the NCAR formulation. The differences have been traced to differences in the neutral transfer coefficients (roughness lengths). As the forcing datasets developed using the NCAR bulk formulae, we recommend using the same bulk formulae for CORE experiments.

We originally went into the NCAR/GFDL comparison thinking that the bulk formulae differences should lead to minor differences in the fluxes. However, the GFDL formulae is somewhat different than NCAR's. The resulting flux differences were too large to ignore, with the goal being to run the models with the same forcing when the SSTs were the same.

5.9   Properly referenced meteorological data

Models should use properly referenced meteorological data consistent with what the bulk formulae expect. Reanalysis meteorological data is commonly distributed at 2m while oceanic turbulent transfer schemes often require 10m data. For accuracy, it is essential that the data be re-referenced to 10m. The re-referencing algorithm and the flux calculation algorithm are closely related. So, one should re-reference using a scheme that is compatible with the flux scheme.

5.10   Same treatment of saltwater vapor pressure

Models should use the same treatment of saltwater vapor pressure. The vapor pressure over seawater is about 2% less than that over fresh water. This difference is not negligible compared to the 20% subsaturation of marine air that drives evaporation. Consequently, the effect should be included in all models participating in a comparison.

5.11   High frequency meteorological data

It is desirable to use high frequency meteorological data. A one month run of an AMIP model was used to explore the flux errors associated with averaged meteorological inputs. With daily winds, temperatures, and humidities, latent heat fluxes are under estimated broadly over the winter storm track band by some 10's of W/m2. There was also a smaller underestimate located in the summer storm track band. Experiments that refined the temporal resolution of the flux inputs individually showed that high frequency winds are most important for reducing the error but temperature and humidity frequency also contribute. When all inputs are given at 6 hourly frequency, the global RMS error is about 1 W/m2 versus near 8 W/m2 for daily inputs.

5.12   River runoff

The river runoff data has only a single time step as it represents annual mean runoff. This data has been spread out from the river mouths in a manner used by NCAR for their climate models. This approach is thought to account for some unresolved mixing that occurs at river mouths in Nature. We provide a remapping scheme which will take the river data and map onto a new grid, so long as the new grid is logically rectangular (such as the GFDL tripolar grid). GFDL can provide some assistance with this remapping if you have problems. Note that if modelers choose their own specification for runoff, perhaps with a seasonal cycle, we recommend that a correction be made to keep the total annual flux of runoff similar to the value in the Large and Yeager (2004) dataset in order to facilitate comparisons.

5.13 Salinity restoring

An issue for comparisons is the strength of the salinity restoring. Relatively strong salinity restoring, analogous to the effective restoring of SSTs, will reduce drift. However, salinity restoring has no physical basis, and so it is desirable to use the weakest possible restoring. A weak restoring also has the benefit of allowing increased variability in the surface salinity and deep circulation.

Unfortunately, when the salinity restoring and effective temperature restoring timescales are very different, the experiment becomes analogous to a mixed boundary condition experiment. The ability of mixed boundary conditions to represent the adjustment of the ocean in the coupled system has been called into question. In particular, mixed boundary condition experiments with strong temperature restoring have been shown to be excessively susceptible to the polar halocline catastrophe, in which a fresh cap develops in high latitudes and shuts down overturning (Zhang et al., 1993).

The effective temperature restoring determined by numerically linearizing the CORE thermal boundary condition is quite strong, yielding piston velocities around 1-2 m/day. The salinity restoring strength chosen for a comparison between NCAR and GFDL simulations with the normal year forcing was two orders of magnitude smaller than this (50m/4years). Under these boundary conditions, the various models documented in Griffies et al. (2009) behaved quite differently, with some groups favoring stronger restoring to stabilize the Atlantic overturning.

Here is a summary of some further points to keep in mind regarding salinity forcing.

- At GFDL, we use a real water flux instead of a salt flux. The salinity restoring may be converted to a water flux, or may remain as a salt flux. In the original simulations documented in Griffies et al. (2009), the salinity restoring was converted to water flux. Recent experiment retain the salinity restoring as a salt flux. The preference for salt flux is simply to maintain diagnostic control over the total water budget arising from P-M+R, and to not have that budget confused with added water from restoring.

- To ensure that there is no accumulation of salt in the model arising from the salinity restoring, it is useful to remove the globally integrated salt content from the restoring field at each model time step. When running with real water fluxes, this normalization occurs on the precipitation minus evaporation implied by the salinity restoring.

- As the ocean SST will deviate from that used to balance the dataset's water content, there is no guarantee that the water will balance as the model integrates. Hence, in addition to removing the global mean salt/water associated with the restoring, we remove the global mean evaporation minus precipitation minus river runoff that results from the bulk formulae. Again, this normalization ensures that no water accumulates in the model, and the normalization is applied at each model time step.

6 Closing remarks

With the release of CORE-IAF.v2, we anticipate far more efforts at GFDL, and elsewhere, to use this dataset for retrospective simulations in support of reanalysis projects, as well as further model-model comparison projects. We will report on these efforts when further work has been completed.

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